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(51) INT CL$^6$
**B41J 2/16**

(52) UK CL (Edition Q )
**B6F** FLQ

(56) Documents Cited
**GB 2107648 A** **JP 63247058 A**
**(SEIKO EPSON) 13.10.88 (See Figure 1, and also WPI**
**Abstract Accession** No. **88-334158/47)**

(58) Field of Search
UK CL (Edition Q ) **B6F FLQ FLT**
INT CL$^6$ **B41J 2/05 2/14 2/16**
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(54) Abstract Title
**Inkjet nozzle with an oxide-nitride or oxide-carbide composite orifice layer**

(57) The nozzle 18 includes a substrate 20 with an upper surface 22 on which an ink energising element 26 (e.g. a thin film resistor) is attached thereto. The nozzle includes an oxide-nitride or oxide-carbide composite orifice layer 41 which includes a lower surface 32 which rests above the upper surface of the substrate, and an upper surface 34 which faces away from the substrate. The composite orifice layer defines a firing chamber 36 which opens through a nozzle aperture 16, and extends downwards with negatively sloped walls through an orifice layer 30 to expose the resistor. A method of forming the nozzle using a series of processing steps including etching, patterning and photoresists to form a sacrificial bump (66,Fig.4G) which is removed by wet oxide etching to form the nozzle (80,Fig.4H) is also disclosed (Figs.4A-H).

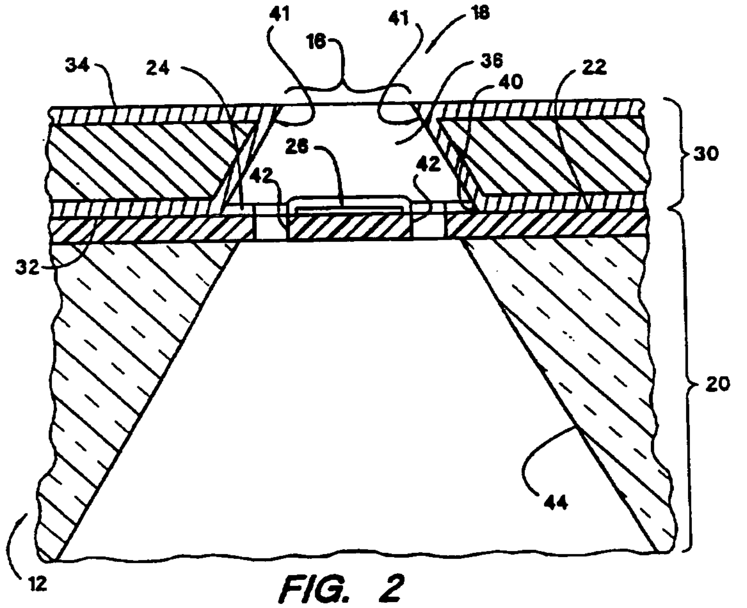

*FIG. 2*

GB 2 333 065 A

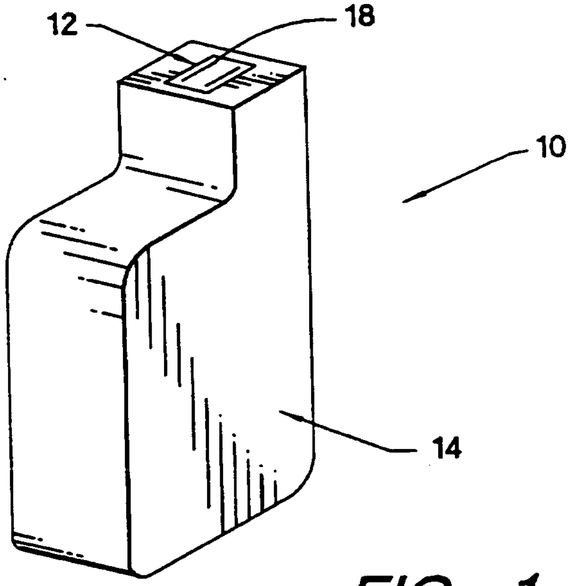

FIG. 1

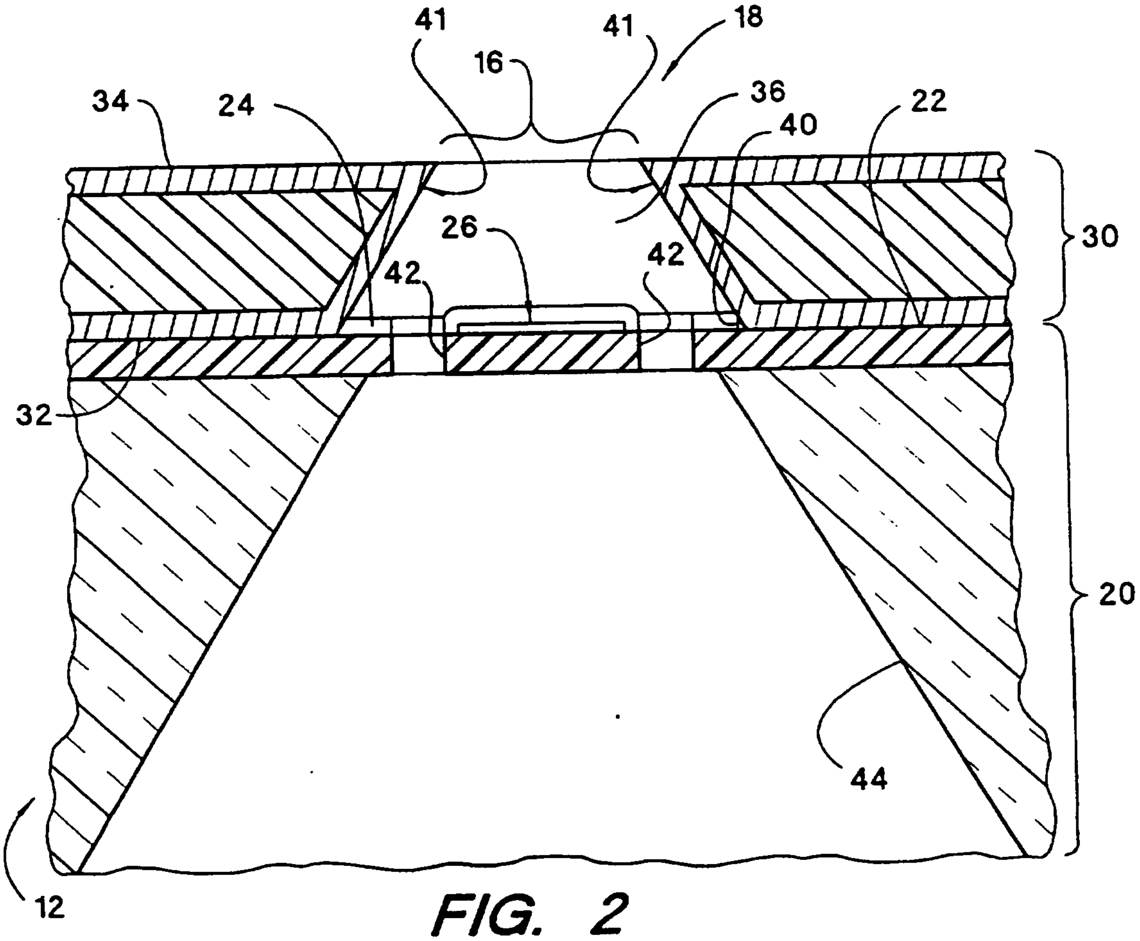

FIG. 2

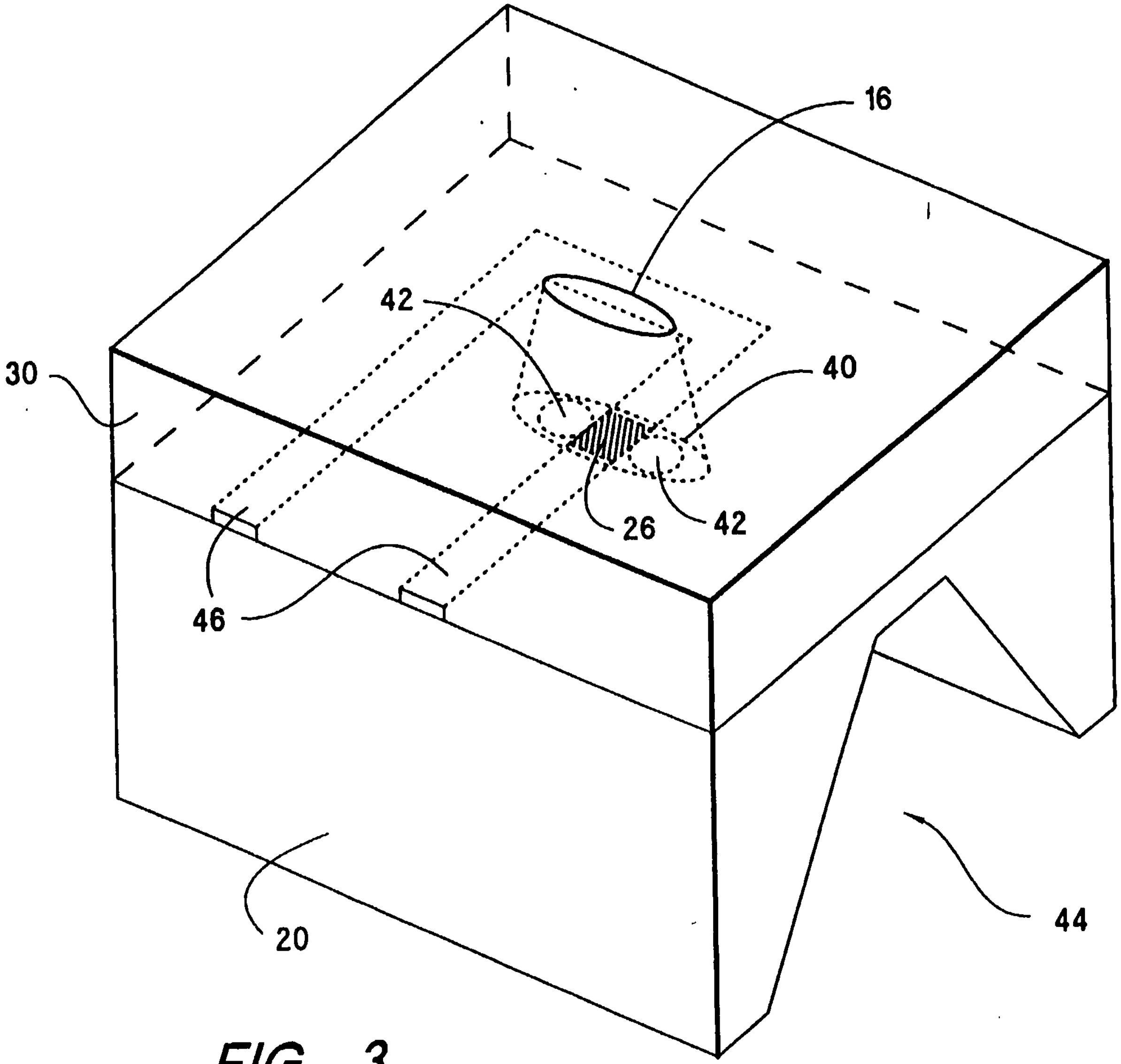

FIG. 3

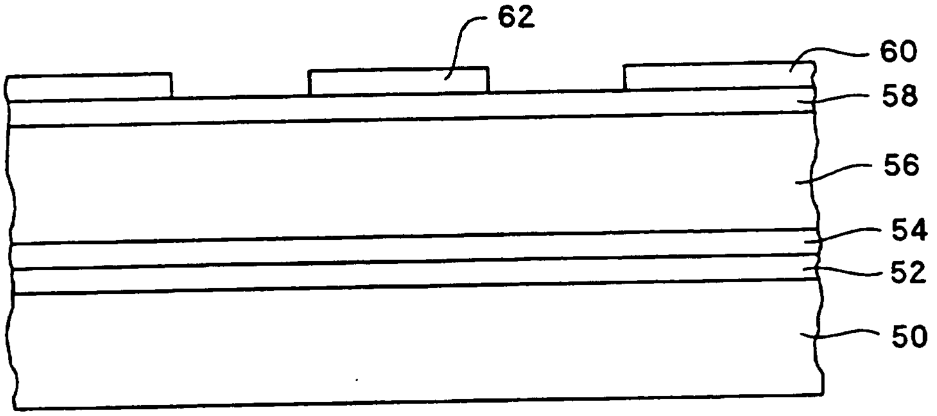

Figure 4A

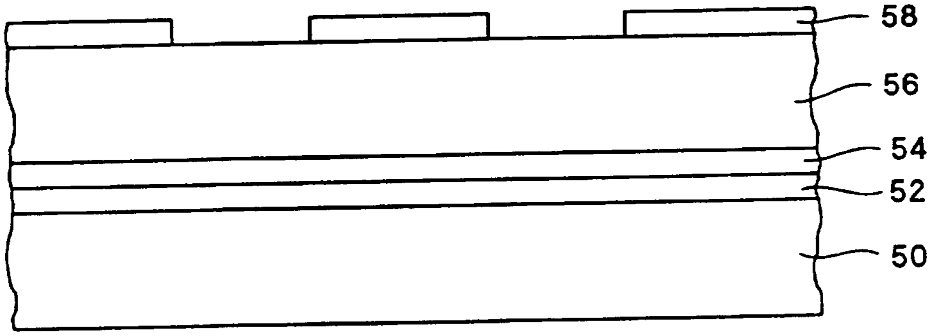

Figure 4B

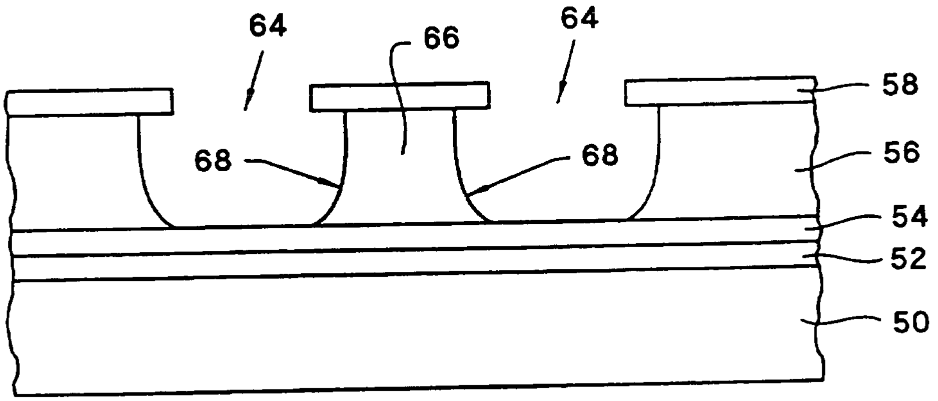

Figure 4C

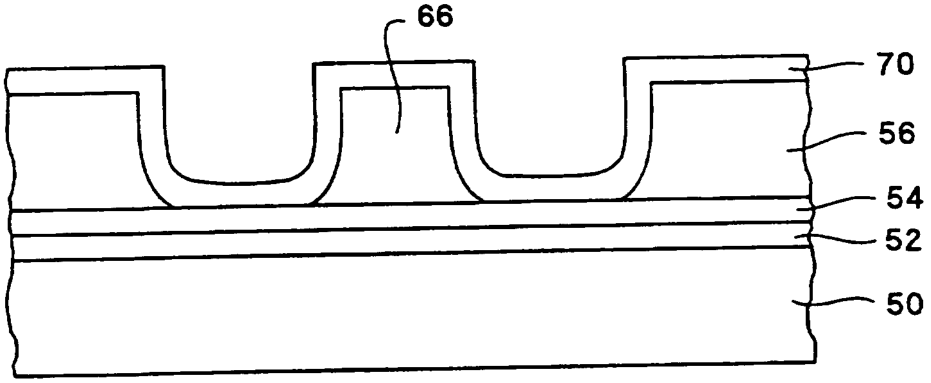

Figure 4D

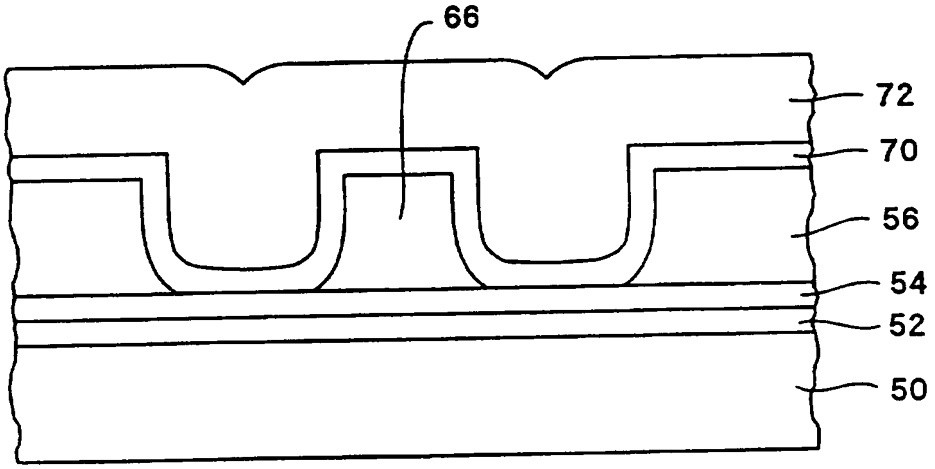

Figure 4E

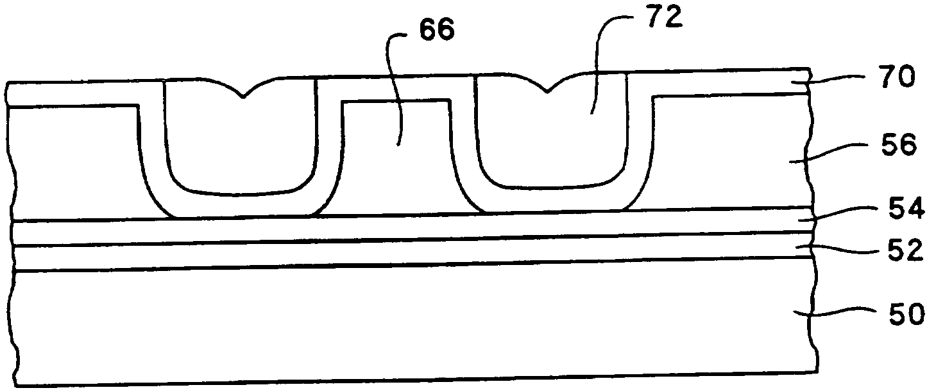

Figure 4F

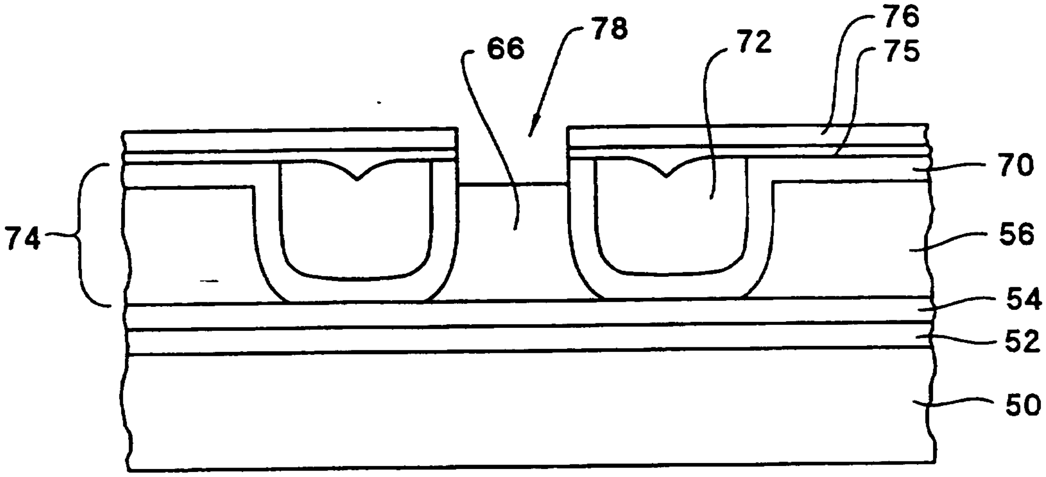

Figure 4G

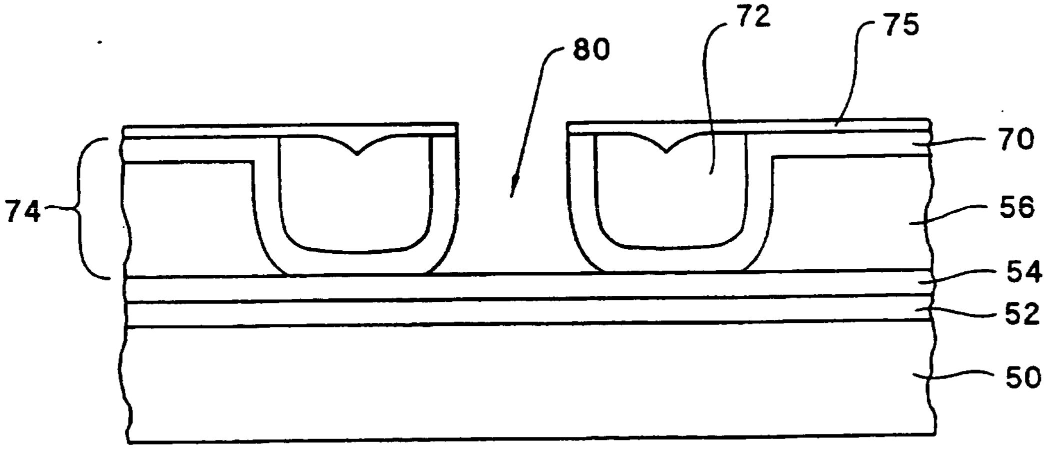

Figure 4H

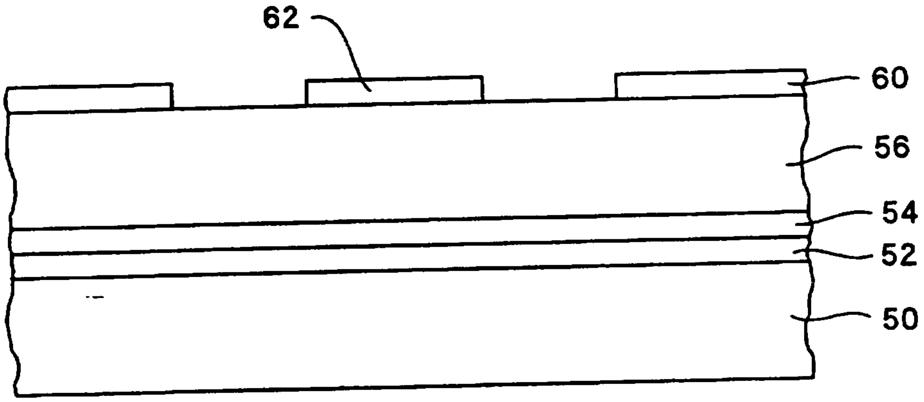

Figure 5A

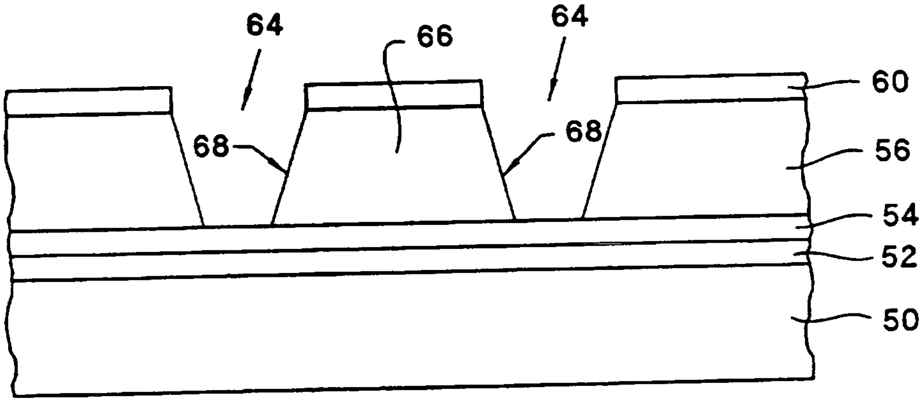

Figure 5B

# INK JET NOZZLE

This invention relates generally to an ink jet print nozzle. In particular, it relates to a monolithic ink jet print nozzle in which inner walls of the ink jet print nozzle are formed from an oxide-nitride or oxide-carbide composition.

Ink jet printing mechanisms use pens that shoot droplets of ink onto a printable surface to generate an image. Ink jet printing mechanisms may be used in a wide variety of applications, including computer printers, plotters, copiers, and facsimile machines. For convenience, the concepts of the invention are discussed in the context of a printer.

An ink jet printer typically includes a print head having a multitude of independently addressable firing units. Each firing unit includes an ink chamber connected to a common ink source, and to an ink jet print nozzle. A transducer within each ink chamber provides the impetus for expelling ink droplets through the associated ink jet print nozzle. Typically, the transducer is a firing resistor which heats the ink until the ink droplets are expelled through the ink jet print nozzle.

Generally, a substrate supports the firing resistors. An orifice layer which includes the ink jet nozzles is attached to the substrate so that each ink jet nozzle corresponds with an associated firing resistor and forms an ink chamber.

To obtain a high resolution printed output, it is desirable to maximize the density of the firing units, requiring miniaturization of the print head components. The substrate that supports the firing resistors and the orifice layer that provides the ink jet nozzle above each resistor are subject to small dimensional variations that can accumulate and limit miniaturization.

Monolithic print heads have been developed through print head manufacturing processes which use photo imaging techniques similar to those used in semiconductor manufacturing. The components are constructed on a flat wafer by selectively adding and subtracting layers of various materials. Using photo-imaging techniques, dimensional variations are limited. Further variations do not accumulate because each layer is registered to an original reference on the wafer.

Existing monolithic print heads are complex to manufacture. Further, the ink jet nozzles are formed from either a polymer or metal material. Polymer and metal materials offer limited performance because the surfaces of these materials can be rough, and because these materials react corrosively with the ink. It is important that the surface of the ink jet nozzle be smooth so as to not interrupt the flow of ink through the ink jet nozzles. Further, corrosive reactions to the ink cause the ink jet nozzles to break down and deteriorate.

It is desirable to have an ink jet nozzle in which the surface of the ink jet nozzle is formed from a material which is smoother than presently existing materials. Further, the material would not react to ink which flows through the ink jet nozzle thereby increasing the useful life of the ink jet nozzle.

The present invention provides a monolithic ink jet nozzle which is formed from an oxide-nitride or oxide carbide composition. These compositions provide an ink jet nozzle which includes a smoother re-entrance surface than presently existing ink jet nozzles. Further, the compositions do not corrosively react to ink passing through the ink jet nozzle. Therefore, the ink jet nozzle is useful for a longer period of time than presently existing ink jet nozzles.

A first embodiment of the invention includes an ink jet nozzle. The ink jet nozzle includes a substrate having an upper surface in which an ink energizing element is attached to the upper surface of the substrate. The ink jet nozzle further includes an oxide-nitride or oxide-carbide composite orifice layer. The composite orifice layer includes a lower surface conformally connected to the upper surface of the substrate, and an exterior surface facing away from the substrate. The composite orifice layer defines a firing chamber. The firing chamber opens through a nozzle aperture in the exterior surface, and extends downward with a negative slope through the composite orifice layer to expose the ink energizing element.

Another embodiment of the invention includes a method of forming an ink jet nozzle over an ink energizing element on an upper surface of a substrate. The method includes the following steps. First, a positive sloped sacrificial oxide bump is created on the surface. Next, a nitride or carbide composite layer and an oxide layer are deposited over the surface and the sacrificial bump. The oxide and composite layers are polished forming an orfice layer. An opening in the orifice layer is created over the sacrificial oxide bump. Finally, the sacrificial oxide bump is removed yielding an ink jet nozzle.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

Figure 1 is a perspective view of an ink jet pen having a print head which includes ink jet nozzles according to the invention.

Figure 2 is a cross-sectional view of an embodiment of the invention.

Figure 3 is a perspective view of the embodiment of the invention shown in Figure 2.

Figures 4A-4H show a series of steps in the formation of an embodiment of the invention.

Figures 5A, 5B show alternative processing steps to the processing steps shown in Figures 4A-4C.

As shown in the drawings for purposes of illustration, the invention is embodied in a monolithic ink jet nozzle. The ink jet nozzle is formed from an oxide-nitride or oxide carbide composition. The composition provides an ink jet nozzle which is smoother than presently used polymer ink jet nozzles. Further, the composition does not react to ink passing through the ink jet nozzle. Therefore, the ink jet nozzle lasts longer than presently existing ink jet nozzles.

Figure 1 is a perspective view of an ink jet pen 10 having a print head 12 which includes ink jet nozzles 18 according to the invention. The ink jet pen 10 also includes a lower portion 14 containing an ink reservoir that supplies ink to the print head 12.

Figure 2 is a cross-sectional view of an embodiment of the invention. This embodiment includes an ink jet nozzle 18. The ink jet nozzle 18 is formed by a frusto-conical firing chamber 36 of an orifice layer 30 attached to a silicon substrate 20. The substrate 20 includes a top surface 22 that is typically coated with a passivation layer 24. A thin film resistor 26 is typically formed over the top surface 22. The top surface 22 of the substrate forms a bottom section of the ink jet nozzle 18 which receives ink. The orifice layer 30 has a lower surface 32 that conformally rests above the top surface 22.

The ink jet nozzle 18 include walls 41 which are negatively sloped from a smaller circular external orifice 16 to a larger circular base periphery 40. The larger circular base periphery 40 is centered around the thin film resistor 26. The ink jet nozzle 18 is aligned on an axis of the thin film resistor 26.

The passivation layer 24 defines several ink supply vias 42 dedicated to the ink jet nozzle 18. The vias 42 are entirely encircled by the lower periphery 40 of the ink jet nozzle 18.

The walls 41 of the ink jet nozzle 18 are formed from a oxide-nitride or oxide-carbide material. The oxide-nitride or oxide-carbide material allows the walls 41 to be smoother than previously possible. Polymer walls, for example, are rougher. Rough walls impede the flow of ink flowing through the ink jet nozzle 18. The smooth walls 41 of the ink jet nozzle 18 of the invention do not impede the flow of ink passing through the frustoconical firing chamber 36 as much as rough polymer or rough metal walls.

The oxide-nitride or oxide-carbide walls 41 of the ink jet nozzle of the invention do not react to ink passing though the frustoconical firing chamber 36. Prior art ink jet nozzles are generally formed from materials which react to ink which makes physical contact with the surface of the nozzles. The reactions reduce the useable life time of the ink jet nozzle. That is, the material of the ink jet nozzle begins to break down, thereby reducing the performance of the ink jet nozzle.

The substrate 20 includes a tapered trench 44 which provides a path for ink to flow between the reservoir 14 and the ink jet nozzle 18.

Figure 3 is a perspective view of an embodiment of the invention. A conductor 46 provides a conductive path for current flowing through the thin film resistor 26. The thin film resistor 26 is a firing resistor which heats the ink until the ink droplets are expelled through the ink jet print nozzle 18.

Figures 4A-4H show a series of processing steps in the formation of an embodiment of the invention. First, a structure as shown in Figure 4A is formed which includes a substrate 50, a first silicon-oxide ($SiO_2$) layer 52 and tantalum (Ta) layer 54. A second silicon-oxide layer 56 is deposited over the Ta layer 54. A poly-silicon layer 58 is deposited over the second-silicon oxide layer 56. Finally, a photo-resist layer 60 is deposited over the poly-silicon layer 58. The photo-resist layer 60 is patterned so that an island 62 of photo-resist is located where an ink jet nozzle is to be formed over the substrate 50. The photo-resist layer 60 pattern can be formed by a standard lithography process.

Figure 4B shows the structure of Figure 4A in which portions of the poly-silicon layer 58 and the photo-resist layer 60 have been removed through dry etching. Dry etching the poly-silicon layer 60 forms a pattern in the poly-silicon layer 58 as determined by the pattern originally formed in the photo-resist layer 60.

Figure 4C shows the structure of Figure 4B in which the second silicon-oxide layer 56 has been wet oxide isotopically etched. An aperture 64 is formed in the silicon-oxide layer as determined by the pattern of the poly-silicon layer 58. The aperture 64 encircles a sacrificial bump 66. The sacrificial bump 66 is located where the ink jet nozzle is to be formed. The sacrificial bump 66 include positively sloped edges 68 which define the negatively sloped edges of the ink jet nozzle to be formed.

Figure 4D shows the structure of Figure 4C in which the poly-silicon layer 58 has been etched away, and a silicon-nitride ($Si_3N_4$) or silicon-carbide (SiC) layer 70 has been deposited over the second silicon-oxide layer 56.

Figure 4E shows the structure of Figure 4D in which a third silicon-oxide layer 72 has been deposited over the silicon-nitride layer 70.

Figure 4F shows the structure of Figure 4E in which the third silicon-oxide layer 72 has been chemically-mechanically polished (CMP). The third silicon-oxide layer 72 is chemically-mechanically polished down to the silicon-nitride or silicon-carbide layer 70 forming an orifice layer 74. The orifice layer 74 includes the second silicon-oxide layer 56, the silicon-nitride or silicon-carbide layer 70, and portions of the third silicon-oxide layer 72.

Figure 4G shows the structure of Figure 4F in which a protective layer 75 and second photo-resist layer 76 have been deposited over the orifice layer 74. The protective layer 75 and the second photo-resist 76 include an opening 78 aligned with the sacrificial bump 66. A portion of the silicon-nitride layer 70 which is aligned with the opening 78 is nitride dry etched down to the silicon-oxide layer 56 leaving the sacrificial bump 66 exposed. The protective layer is either a silicon-carbide and a silicon-nitride. Silicon-carbide may be the preferred protective layer 75 material because silicon-carbide provides a very hard surface.

Figure 4H shows the structure of Figure 4G in which the exposed sacrificial bump 66 and the second photo-resist layer 76 have been removed through wet oxide etching. Removing the sacrificial bump 66 results in the formation of an ink jet nozzle 80 in the orifice layer 74.

Figures 5A, 5B show alternative processing steps to the processing steps shown in Figures 4A, 4B, 4C. First, a structure as shown in Figure 5A is formed which includes a substrate 50, a first silicon-oxide ($SiO_2$) layer 52 and tantalum (Ta) layer 54. A second silicon-oxide layer 56 is deposited over the Ta layer 54. Finally, a photo-resist layer 60 is deposited over the silicon-oxide layer 56. The photo-resist layer 60 is patterned so that an island 62 of photo-resist is located where an ink jet nozzle is to be formed over the substrate 50. The photo-resist layer 60 pattern can be formed by a standard lithography process.

Figure 5B shows the structure of Figure 5A in which the second silicon-oxide layer 56 has been dry etched. An aperture 64 is formed in the silicon-oxide layer as determined by the pattern of the photo-resist layer 60. The aperture 64 encircles a sacrificial bump 66. The sacrificial bump 66 is located where the ink jet nozzle is to be formed. The sacrificial bump 66 include positively sloped edges 68 which define the negatively sloped edges of the ink jet nozzle to be formed.

Subsequent processing steps to the structure shown in Figure 5B are the same as those shown in Figures 4D-4H.

Although specific embodiments of the invention have been described and illustrated, the invention is not to be limited to the specific forms or arrangements of parts so described and illustrated. The invention is limited only by the claims.

CLAIMS:

1. A monolithic ink jet nozzle comprising:

a substrate having an upper surface, an ink energizing element attached to the upper surface of the substrate; and

an oxide-nitride composite orifice layer, the oxide-nitride composite orifice layer having a lower surface conformally connected to the upper surface of the substrate, and an exterior surface facing away from the substrate, the oxide-nitride composite orifice layer defining a firing chamber, the firing chamber opening through a nozzle aperture in the exterior surface, and extending downward with a negative slope through the oxide-nitride composite orifice layer to expose the ink energizing element.

2. The monolithic ink jet nozzle as recited in claim 1, wherein the oxide-nitride composite orifice layer comprises nitride.

3. The monolithic ink jet nozzle as recited in claim 1, wherein the oxide-nitride composite orifice layer comprises oxide.

4. The monolithic ink jet nozzle as recited in claim 1, wherein the ink energizing element is a resistor.

5. A monolithic ink jet nozzle comprising:

a substrate having an upper surface, an ink energizing element attached to the upper surface of the substrate; and

an oxide-carbide composite orifice layer, the oxide-carbide composite orifice layer having a lower surface conformally connected to the upper surface of the substrate, and an exterior surface facing away from the substrate, the oxide-carbide composite orifice layer defining a firing chamber, the firing chamber opening through a nozzle aperture in the exterior surface, and extending downward with a negative slope through the oxide-carbide composite orifice layer to expose the ink energizing element.

6. A method of forming an ink jet nozzle over an ink energizing element on an upper surface of a substrate, the method comprising:

creating a positive sloped sacrificial oxide bump on the surface;

depositing an etch stop layer and an oxide layer over the surface and the sacrificial bump;

polishing the oxide to the etch stop layer forming an orifice layer;

creating an opening in the orifice layer over the sacrificial oxide bump; and

removing the sacrificial oxide bump.

7. The method of forming an ink jet nozzle as recited in claim 6, wherein the step of creating a sacrificial bump comprises:

depositing a silicon-oxide layer over the upper surface of the substrate;

depositing a hard mask layer over the silicon-oxide layer;

removing a pattern of the hard mask layer so that an island of hard mask layer is located over the ink energizing element;

wet oxide isotropic etching the silicon-oxide forming apertures in the silicon-oxide where the hard mask layer has been removed; and

etching the remaining hard mask layer and any residual resist.

8. The method of forming an ink jet nozzle as recited in claim 6, wherein the step of creating a sacrificial bump comprises:

depositing a hard mask layer over the silicon layer;

removing a pattern of the hard mask layer so that an island of hard mask layer is located over the ink energizing element;

dry etching the silicon-oxide forming apertures in the silicon-oxide where the hard mask layer has been removed; and

etching the remaining hard mask layer and any residual resist.

9. The method of forming an ink jet nozzle as recited in claim 7, wherein the step of removing a pattern of the hard mask layer comprises:

depositing a resist layer over the hard mask layer so that an island of resist is located over the ink energizing element; and

dry etching the hard mask layer so that the hard mask layer is removed where the resist layer does not exist.

10. The method of forming an ink jet nozzle as recited in claim 7, wherein the step of depositing a hard mask layer comprises depositing a poly-silicon layer.

11. The method of forming an ink jet nozzle as recited in claim 6, wherein the step of depositing an etch layer comprises depositing a nitride layer.

12. The method of forming an ink jet nozzle as recited in claim 6, wherein the step of depositing an etch layer comprises depositing a carbide layer.

13. The method of forming an ink jet nozzle as recited in claim 6, wherein the step of polishing the oxide to the etch stop layer comprises chemically-mechanically polishing the oxide layer to the etch stop layer.

14. The method of forming an ink jet nozzle as recited in claim 6, wherein the step of removing the sacrificial oxide bump comprises:

forming a hole in the orifice layer exposing the sacrificial oxide bump; and

wet etching the sacrificial oxide bump forming the ink jet nozzle.

15. The method of forming an ink jet nozzle as recited in claim 14, wherein the step of forming a hole in the orifice layer comprises:

depositing a photo-resist pattern over the orifice layer; and

dry etching the orifice layer forming a hole where the photo-resist does not exist.

16. An inkjet nozzle substantially as herein described with reference to each of the accompanying drawings.

17. A method of forming an inkjet nozzle substantially as herein described with reference to each of the accompanying drawings.

14

**Application No:** GB 9900441.8
**Claims searched:** 1-5,16

**Examiner:** Gary Williams
**Date of search:** 21 April 1999

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): B6F: FLQ,FLT

Int Cl (Ed.6): B41J: 2/05,2/14,2/16

Other: Online: WPI

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
|---|---|---|
| A | GB 2107648 A (CANON) See Fig.2A, page 3 lines 79-92 | 1,5 |
| A | JP 63247058A (SEIKO EPSON) 13.10.88 (See Figure 1, and also WPI Abstract Accession No. 88-334158/47). | 1,5 |

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

# (12) UK Patent Application (19) GB (11) 2 086 807 A

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**B41J 3/04**
(52) Domestic classification
**B6F LQ**
(56) Documents cited
**None**
(58) Field of search
**B6F**

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## (54) Method of manufacturing a jet nozzle plate for an ink-jet printing head

(57) A plate 1 of chemically etchable material is first provided with a bore 2 for each nozzle, the bore having a diameter larger than the desired internal diameter of the ultimate jet nozzle. Recesses 4 are then formed and then the whole of the plate including the wall of each bore is covered with a layer 7 of chemically deposited etch-resistant material. Subsequently the etch-resistant layer on the raised portion of the plate around each bore 2 is removed by grinding the front side of the plate down to the level, (see dotted line) of the etch-resistant layer 7 in the recesses 4. The material of the plate exposed by the grinding is then removed by etching to leave the etch-resistant layer 7 on the wall of each bore 2 projecting as a cylindrical tube 8 from the front side of the plate to form a jet nozzle.

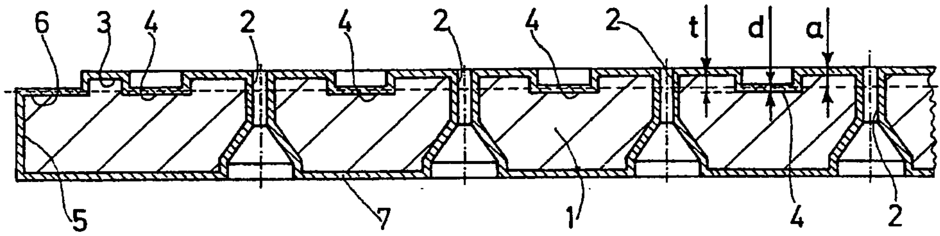

Fig.4

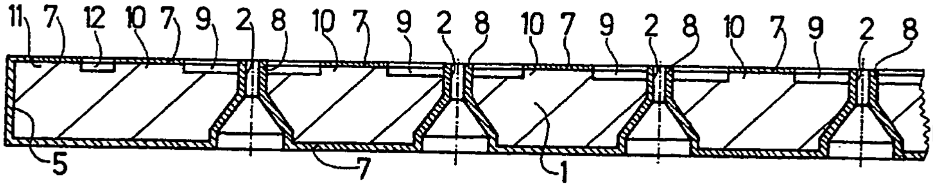

Fig.6

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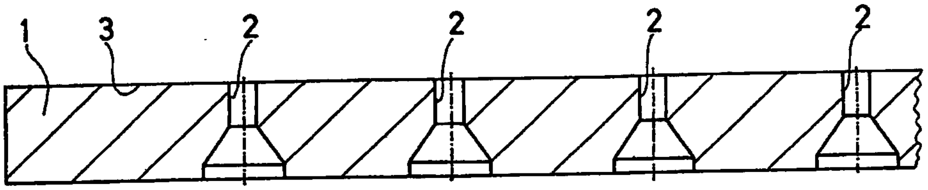

Fig.1

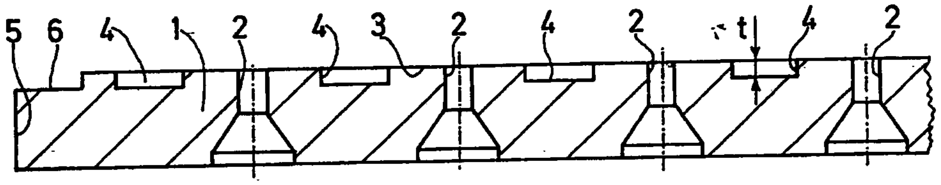

Fig.2

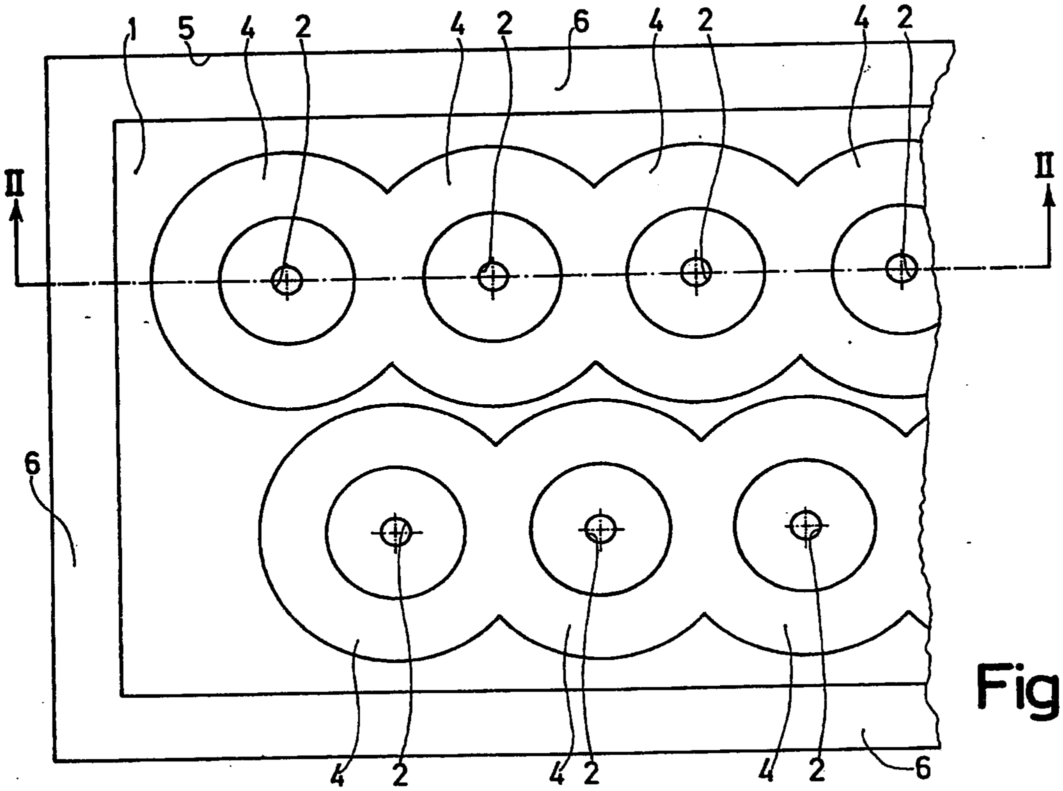

Fig.3

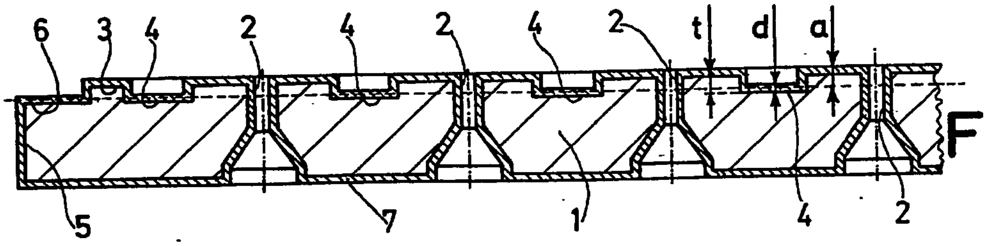

Fig.4

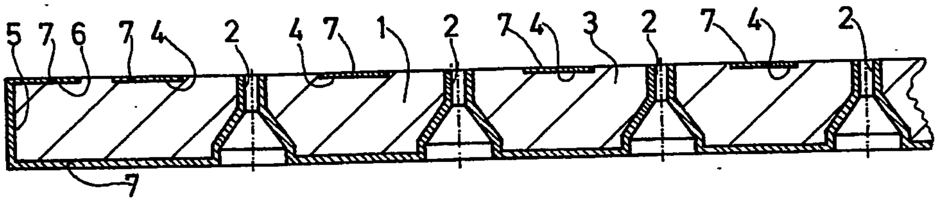

Fig.5

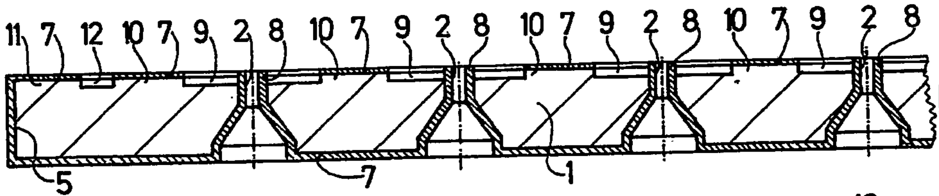

Fig.6

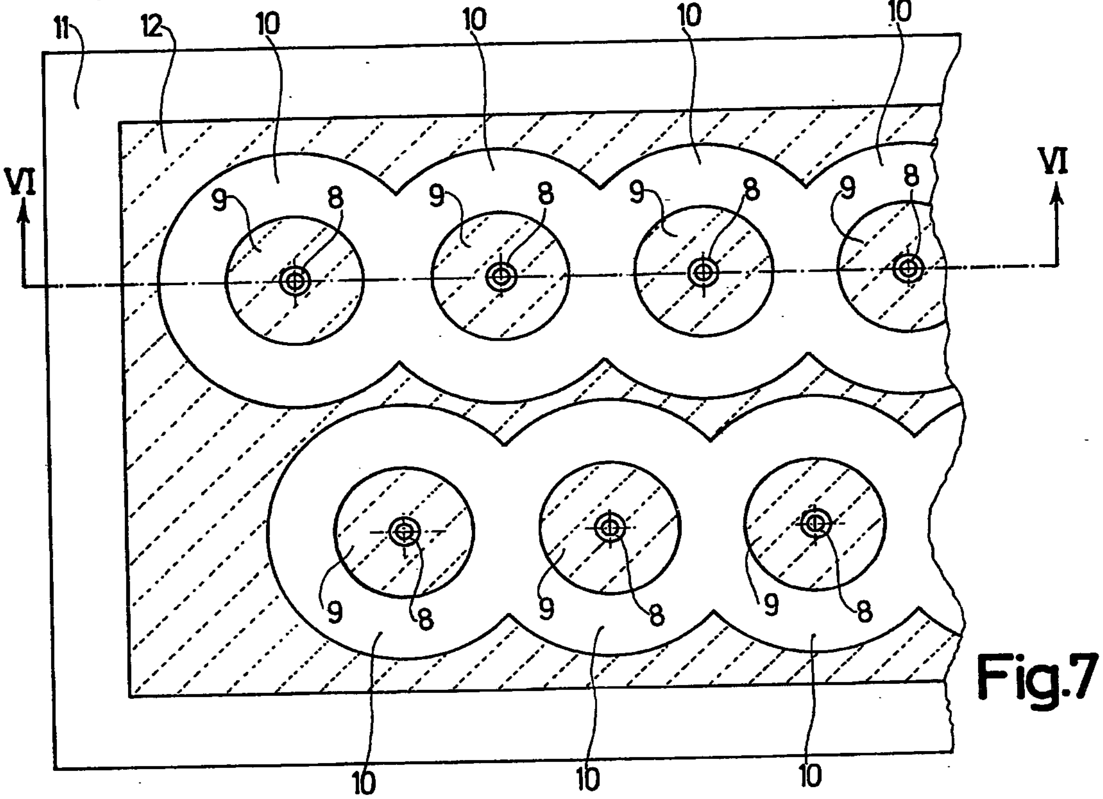

Fig.7

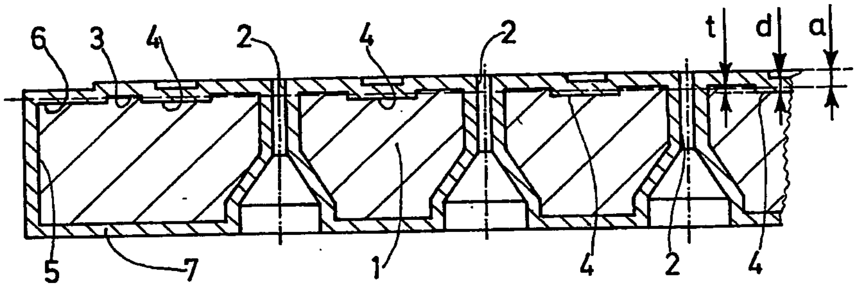

Fig.8

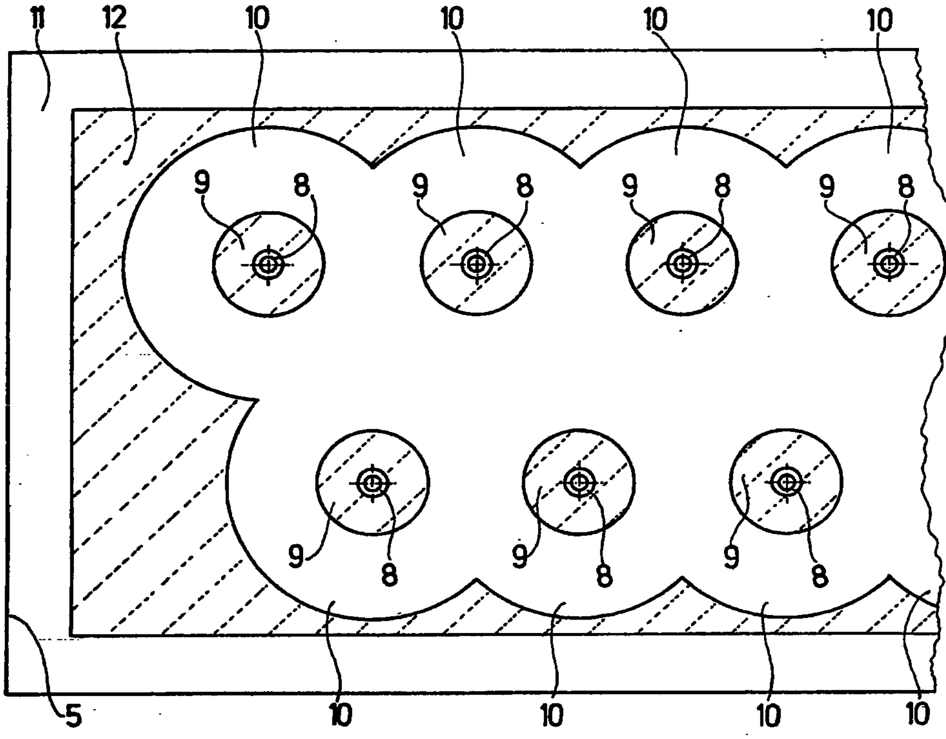

Fig.9

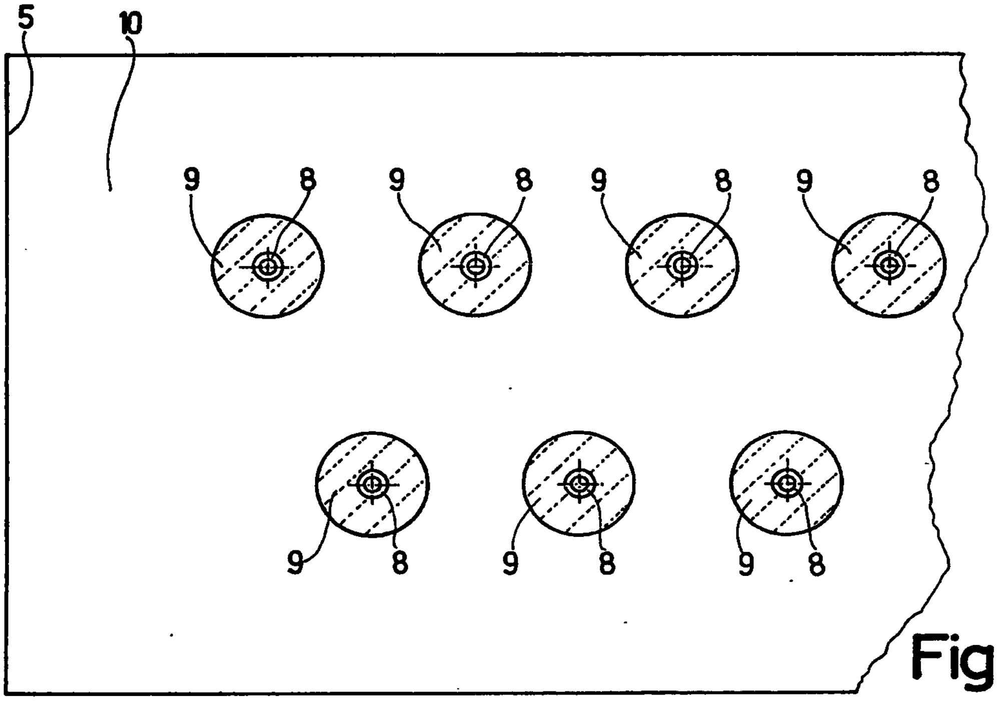

Fig.10

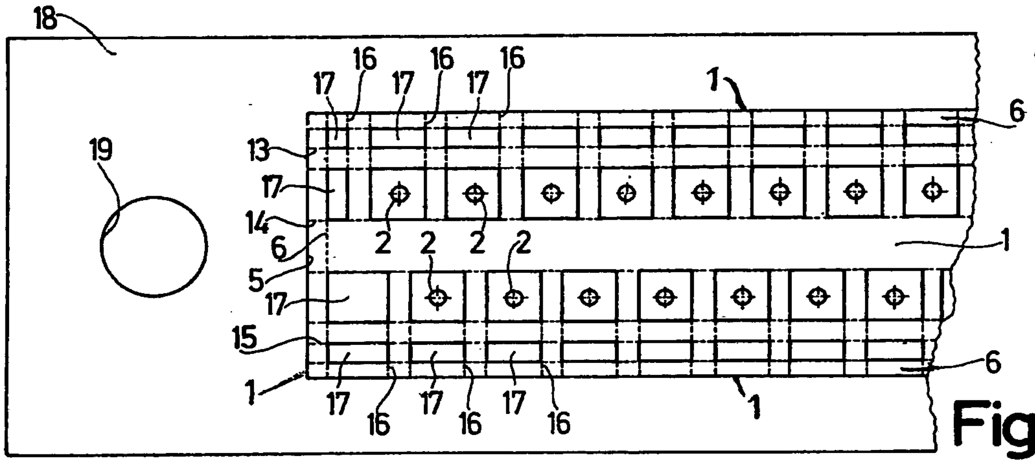

Fig.11

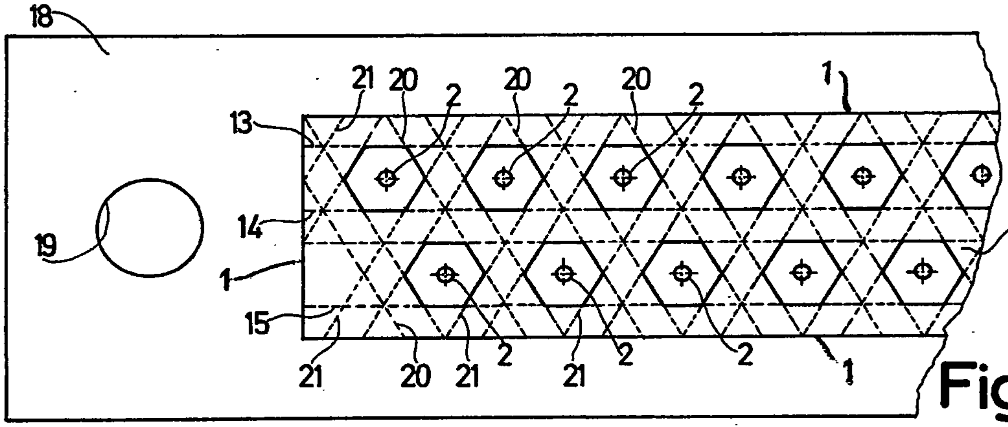

Fig.12

## SPECIFICATION

## Method of manufacturing a jet nozzle plate for an ink-jet printing head

The invention relates to a method of manufacturing a jet nozzle plate for an ink-jet printing head, which plate comprises a jet nozzle having a given internal diameter.

IBM Technical Disclosure Bulletin, Vol. 15, No. 9, pages 2845 and 2846, discloses a method of manufacturing such a jet nozzle plate, in which a base plate from which the jet nozzle plate is to be formed and which is made of a chemically etchable material is first provided with a bore having a diameter larger than the desired internal diameter of the ultimate jet nozzle, and a wire is concentrically inserted in the bore, the diameter of said wire corresponding to the desired internal diameter of the ultimate jet nozzle, after which the whole of the base plate including the wall of the bore is covered with a layer of etch-resistant material which is chemically deposited on the plate. The wire is then removed by etching so that the jet nozzle is freed. A given length of the wire projects from the bore, so that etch-resistant material is also deposited on this projecting part of the wire and a jet nozzle is formed which consists of a tube whose free end projects from the jet nozzle plate. A method of this kind is not easy to perform, particularly in view of the centering of the wire in the bore.

For the manufacture of a jet nozzle plate in which a jet nozzle is formed by a tube whose free end projects from the jet nozzle plate, it may be stated that even though favourable properties are thus obtained as regards the ejection of droplets of ink from such a jet nozzle plate, it is difficult to cap the jet nozzle exactly with a capping device when the jet nozzle is not in use, for example, in the rest condition of the ink-jet printing head, in order to prevent drying of the ink in the jet nozzle and hence clogging of the nozzle so that it can no longer be used. This difficulty arises *inter alia* because the capping device, customarily consisting of a slightly elastic cushion, is not arranged exactly flat against the end face of the tube but is curved over this end, so that it does not completely cover the jet nozzle. In this respect German Auslegeschrift 23 62 576 has already proposed an embodiment of the jet nozzle plate in which an annular trough is provided around a jet nozzle, said trough being adjoined by a land having a plane surface which is situated at the same level as the end face of the jet nozzle, which itself is also tubular. However, said German Auslegeschrift 23 63 576 does not describe how such a jet nozzle plate can be efficiently manufactured.

According to the present invention there is provided a method of manufacturing a jet nozzle plate for an ink-jet printing head, which plate comprises a jet nozzle having a given internal diameter, wherein a base plate from which the jet nozzle plate is to be formed and which is made of a chemically etchable material is first provided with a bore which extends through the base plate and of which at least a portion that opens out of one side of the plate is cylindrical and has a diameter larger than the desired internal diameter of the ultimate jet nozzle, material is then removed from said one side of the base plate by milling so as to leave on said side of the base plate a portion which adjacently surround the bore and is raised with respect to the adjoining portion of said side of the base plate, the whole of the base plate including the wall of the bore is subsequently covered with a layer of etch-resistant material which is chemically deposited on the plate to a thickness equal to half the difference between the diameter of said cylindrical portion of the bore and the desired internal diameter of the ultimate jet nozzle, after which the etch-resistant layer is removed from at least the top of the raised portion on said one side of the base plate by grinding in a plane perpendicular to the axis of the bore to a depth which at least equals the thickness of said layer but which is smaller than the sum of the thickness of the layer and the depth to which material was removed from said one side of the base plate by milling, and finally material of the base plate surrounding the bore and exposed by the grinding is removed by etching to leave the etch-resistant material which was deposited on the wall of said cylindrical portion of the bore projecting as a cylindrical tube from said one side of the base plate to form the jet nozzle, the tube being surrounded by a trough formed in said one side of the base plate by the etching.

Preferably, the grinding is continued until the etch-resistant layer on that part of said one side of the base plate from which material was removed by milling has been partially ground down. This part of the base plate, with the etch-resistant layer thereon, is then left by the subsequent etching process as a land on said one side of the base plate, the top surface of the land lying in the same plane as the end face of the tube forming the jet nozzle. The top surface of the land consequently provides an accurate supporting surface for a capping device for the jet nozzle plate.

The removal of material from said one side of the base plate by milling may form an annular recess in said side of the plate, which recess surrounds and is spaced from the bore in the base plate. The recess can be formed simply and accurately by means of an end-milling cutter.

Alternatively, the removal of material from said one side of the base plate by milling may be effected by milling straight grooves in said side of the plate, the grooves intersecting one another so as to form around the bore in the base plate and spaced therefrom a recess in the form of a channel of polygonal shape in said side of the base plate. The grooves may be formed by means of a side-milling cutter.

Material may be removed from said one side of the base plate by milling to a depth which is smaller than the thickness of the etch-resistant layer subsequently deposited thereon. Because the amount by which this side of the base plate is subsequently ground down must be at least equal to the thickness of the layer but smaller than the sum of the thickness of this layer and the depth of which material was removed from said side of the base plate by milling, grinding may be comparatively critical if the milling depth is small. Preferably, therefore, the removal of material from said one side of the base plate by milling is carried out to a depth which is greater than the thickness of the etch-resistant layer subsequently deposited on the base plate, the subsequent grinding being continued until the etch-resistant layer on that part of said one side of the base plate from which material was removed by milling has been partially ground down. The amount of grinding is thus greater, so that the grinding operation can be better controlled.

In those embodiments in which the removal of material from said one side of the base plate by milling leaves in this side of the plate a recess surrounding and spaced from the bore in the plate, a rebate may be milled in said one side of the base plate around the edge thereof prior to the deposition of the layer of etch-resistant material, the rebate having the same depth as the recess surrounding the bore in the base plate. This rebate results in the production of an additional land on the base plate to provide a further supporting surface for a capping device.

For manufacturing a jet nozzle plate having a plurality of jet nozzles the base plate may be formed with a corresponding plurality of said bores, and around each bore at a distance therefrom a recess may be milled in said one side of the base plate so as to leave on this side of the plate a raised portion adjacently surrounding the respective bore, the recess being formed so as to merge with one another. This results in the formation of a continuous land on the base plate to provide a continuous supporting surface for a capping device.

To obtain the maximum supporting surface for a capping device, material may be removed by milling from the whole of said one side of the base plate except for the portion surrounding the bore.

Some embodiments of the invention will now be described in detail with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view of a part of a base plate formed with a plurality of bores for jet nozzles,

Fig. 2 is a sectional view taken on the line II—II in Fig. 3, showing the base plate of Fig. 1 formed with recesses around the bores,

Fig. 3 is a front elevation of part of the base plate of Fig. 2,

Fig. 4 is a sectional view showing the base plate of Fig. 2 after the deposition of the etch-resistant layer,

Fig. 5 is a sectional view showing the base plate of Fig. 4 after the grinding of the front side thereof,

Fig. 6 is a sectional view taken on the line VI—VI in Fig. 7, showing the base plate of Fig. 5 after the etching which produces the finished jet nozzle plate,

Fig. 7 is a front elevation of the jet nozzle plate shown in Fig. 6,

Fig. 8 is a view similar to Fig. 4, showing a base plate formed with recesses whose depth is smaller than the thickness of the etch-resistant layer,

Fig. 9 is a front elevation of part of a finished jet nozzle plate in which the lands surrounding the troughs around the jet nozzles all merge with one another to form a continuous surface for supporting a capping device.

Fig. 10 is a view similar to Fig. 9, showing a finished jet nozzle plate in which one continuous land surrounding the troughs around the jet nozzles extends as far as the edges of the plate,

Fig. 11 is a view similar to Fig. 3, showing a base plate in which recesses in the form of channels of rectangular shape are formed around the bores in the plate by milling a pattern of straight intersecting grooves in the front side of the base plate, and

Fig. 12 is a view similar to Fig. 11, showing a base plate in which a pattern of straight intersecting grooves is milled in the front side of the base plate such as to leave raised portions of hexagonal shape surrounding the bores in the plate.

The principle of the method of manufacturing a jet nozzle plate in accordance with the invention will be described in detail hereinafter with reference to Figs. 1 to 7. Fig. 1 shows part of a base plate 1 for a jet nozzle plate, which base plate consists of a chemically etchable material, preferably brass. For this embodiment it is assumed that the jet nozzle plate is to comprise two parallel rows of jet nozzles, the jet nozzles in one row being staggered with respect to the jet nozzles in the other row and each row comprising, for example, twelve jet nozzles. Obviously, it is alternatively possible to provide more than two rows of jet nozzles or only one row of jet nozzles, and the number of jet nozzles may also be different, even to the extent of having a single jet nozzle. This is completely dependent on how the characters are formed by means of the ink-jet printing head for which the jet nozzle plate is intended. To form the individual jet nozzles, the base plate 1 is first provided with bores 2 which are cylindrical at the front 3 of the base plate, widen in a conical manner towards the rear of the plate and finally become cylindrical again. It has been found that such a shape, which is known *per se*, is advantageous with respect to the ultimate configuration of the ink-jet nozzles and the connection of the ink supply ducts to the individual jet nozzles of the jet nozzle plate (which is irrelevant to the invention). However, it is also possible to give the bores 2 a wholly cylindrical shape. The diameter of the bores 2 is larger than the internal diameter of the ultimate jet nozzle. This offers the advantage that it simplifies the formation of the bores 2 since the internal diameter of a finished jet nozzle is usually very small, for example, of the order of 0.05 mm.

The next step in the manufacture of the jet nozzle plate is the milling of a recess 4 around each bore 2 in the front side 3 of the base plate 1, the recess being concentric with and spaced from the bore, as shown in Figs. 2 and 3. The recesses 4 in this embodiment are of annular shape and can be very accurately formed by means of an end-milling cutter. The inner and outer diameters of the recesses in this embodiment are so chosen that adjacent recesses in each row merge and open into one another. It is alternatively possible to give the recesses diameters such that adjacent recesses do not open into one another, each bore 2 then being surrounded by a recess which has the shape of a closed circular ring. It has been found that the inner diameter of the recesses should preferably amount to eight times the internal diameter of the ultimate jet nozzles to ensure sufficient freedom around the tubes which, as will be described later herein, form the finished jet nozzles. The outer diameter of the recesses is dependent on the distance between adjacent bores or finished jet nozzles, which distance may be of the order of, for example, 0.5 mm. The depth *t* of the recesses 4 may be of the order of 0.04 mm when the other dimensions have the values given above. It has also been found that for reasons which will be explained later herein, a rebate 6 should preferably be milled in the front side of the base plate around the edge thereof to the same depth as the recesses 4 surrounding the bores 2.

The whole of the base plate 1, including the walls of the bores 2, is subsequently covered with a layer 7 of an etch-resistant material of a kind which can be deposited on the plate 1 by a chemical process, for example, nickel. The choice of the thickness *d* of this layer is governed by the fact that the internal diameter of the ultimate jet nozzles will be determined by the thickness of this layer. The thickness of the layer is consequently made equal to half the difference between the diameter of the front cylindrical portions of the bores 2 and the desired internal diameter of the ultimate jet nozzle. A value of approximately 0.03 mm may be chosen for the thickness of the layer 7. The base plate 1 is now in the condition shown in Fig. 4. As can be readily seen, the depth *t* of the recesses 4 in this embodiment is chosen so that it exceeds the thickness *d* of the layer 7.

In the next step, the front 3 of the base plate 1 is ground down by an amount *a* which at least equals the thickness *d* of the layer 7 but which is smaller than the sum of the thickness *d* of the layer 7 and the depth *t* of the recesses 4. In this embodiment, this amount *a* is so chosen within the said limits that during the grinding down of the front of the base plate, the portions of the layer 7 that cover the bottoms of the recesses 4 and the rebate 6 are also slightly ground down as shown in Figs. 4 and 5. Thus, around each bore, and between the recesses 4 and the rebate 6, material of the base plate 1 is exposed, the originally continuous layer 7 of etch-resistant material thus being divided into separate layers 7. Because grinding is continued until the layers on the bottoms of the recesses 4 and the rebate 6 are also ground down slightly, it is ensured that there are no raised edges on these layers, so that the front of the base plate forms a completely flat surface.

Finally, at the front of the base plate 1, exposed material of the plate is removed by etching, leaving the etch-resistant material of the remaining layers 7 intact. This leaves the layers 7 in the bores 2 projecting from the base plate 1 as free cylindrical tubes 8, each of which forms a jet nozzle, as shown in Figs. 6 and 7. As a result of the removal of material of the base plate 1 around each of the tubes 8, each of these tubes is surrounded by an annular trough 9 which is in turn surrounded by a land 10 having a plane surface which has not been affected by the etching operation since it is formed by a layer 7 of etch-resistant material. Accordingly, each land 10 consists of the material of the base plate at its base and of the material of the layer 7 at its top. The outer diameter of the troughs 9 corresponds to the inner diameter of the recesses 4. A land 11 also extends around the edge 5 of the base plate on the front side thereof as a result of the etching away of material of the plate between the layers 7 of etch-resistant material on the bottoms of the recesses 4 and the layer on the bottom of the rebate 6. Thus, a trough 12 is formed in the front side of the base plate between the lands 10 and the land 11. This trough and the troughs 9 around the tubes 8 are shown shaded in Fig. 7. Because the flat surfaces of the lands 10 and 11 and the end faces of the tubes 8 forming the jet nozzles are all formed by the one grinding operation, they are all situated in one plane perpendicular to the axes of the jet nozzles.

As can be seen, a jet nozzle plate manufactured by the above method offers the desired advantages, namely, on the one hand the individual jet nozzles consist of free cylindrical tubes which are very effective for the ejection of ink droplets whilst on the other hand the troughs 9 which provide the free space around the individual jet nozzles are surrounded by lands 10 having flat surfaces which are situated in the same plane as the end surfaces of the tubs 8 forming the jet nozzles, so that these lands 10 can be used as supporting surfaces for a capping device when the jet nozzle plate is capped by means of such a device in order to prevent drying of the ink present in the jet nozzles and hence clogging of the jet nozzles. Moreover, the lands 10, being situated at a distance from the tubes 8, also after protection against damage to these comparatively vulnerable tubes.

In the above embodiment, as can be seen in Figure the layers 7 of the lands 10 which surround the jet nozzles 8 form a continuous surface along each row of nozzles. This is due to the fact that the relevant recesses 4 in which these layers were formed open into one another. It has been found that such a formation of the layers 7 is very advantageous since it assists uniform capping of the jet nozzles. As has already been suggested, however, it is alternatively possible for the recesses 4 to be completely separate from one another. In that case each jet nozzle 8 is surrounded by a separate layer 7, which may be found sufficient for efficient capping of the jet nozzles.

With reference to Fig. 4 it has already been stated that the depth *t* of the recesses 4 is preferably chosen to be larger than the thickness *d* of the subsequently deposited layer 7. The same result as regards the ultimate form of the jet nozzle plate, however, can also be obtained by making the depth *t* smaller than the thickness *d*, as shown in Fig. 8. In that case the front of the base plate must be ground down by an amount *a* which is again equal to or larger than the thickness *d* but smaller than the sum of the thickness *d* and the depth *t*. Because the depth *t* itself is now smaller the grinding may be more critical in this case but less material of the base plate has to be removed, which may also be advantageous in given circumstances. The etching of such a base plate after the grinding has been completed is effected in exactly the same way as in the first embodiment.

In the embodiment shown in Fig. 9 the layers 7 of the lands 10 which surround the jet nozzles 8 form a continuous surface which extends both along each row of nozzles and from row to row. This provides an even better supporting surface for a capping device. To produce this surface the recesses 4 in which the relevant layers 7 are formed are constructed to merge with one another both between the bores 2 in each row of bores and between the rows of bores. A similar result could be obtained by providing a further recess between the two rows of bores 2 in the embodiment described with reference to the Figs. 1 to 7, said further recess connecting the recesses 4 surrounding the bores of one row with the recesses 4 surrounding the bores of the other row.

In the embodiment shown in Fig. 10, a maximum supporting surface for a capping device is obtained. In this embodiment the jet nozzles are surrounded by one continuous land 10 which extends to the edge 5 of the base plate and which forms one continuous surface on the front side of the plate for supporting a capping device. This continuous land is obtained by removing material of the base plate, by further milling, from the whole of the front side of the plate to the same depth as that of the recesses 4, leaving only an annular raised portion around each of the bores 2. The subsequent application of a layer of etch-resistant material to the plate and the grinding and etching processes are carried out in the same way as described above. It has been found that such a jet nozzle plate offers very good results in practice.

In the embodiment of Fig. 11, the base plate 1 is provided with recesses by milling straight grooves in the front side of the plate, the grooves intersecting one another so as to form around each bore 2 a recess in the form of a channel of polygonal shape, in this case rectangular, which channel is spaced from the respective bore to leave a raised portion of corresponding polygonal shape on the front surface of the base plate surrounding the bore. In Fig. 11 there are three grooves 13, 14 and 15 extending parallel to the two rows of bores 2, the grooves 13 and 15 being located outside the rows of bores and the groove 14 between the rows, and a plurality of grooves 16 extending at right angles to the rows of bores, one groove 16 being located between every two adjacent bores in each row. A rebate 6 is again provided around the edge of the plate 1. This rebate and all the recesses again have the same depth and can readily be formed by means of a side-milling cutter. Outside the two rows of bores 2, further raised portions 17 are left on the front surface of the base plate 1. These portions, however, can also be removed by milling if a maximum supporting surface for a capping device is to be obtained, as in the embodiment shown in Fig. 10. The further steps in the method of manufacturing the jet nozzle plate shown in Fig. 11 are identical to those already described with reference to Figs. 4, 5, 6 and 7 so that all the raised portions on the front surface of the base plate of Fig. 11 are thereby converted into troughs in the finished jet nozzle plate, and all the recesses and the rebate in the front surfaces of the base plate of Fig. 11 are converted into lands on the finished plate.

In this embodiment, the base plate 1 is formed by a raised part of a larger plate 18 in order to facilitate the attachment of the very small jet nozzle plate to the ink-jet printing head. For example, this can be effected by means of screws, for which purpose corresponding holes 19 are provided in the plate 18.

The embodiment of Fig. 12 comprises a base plate similar to that of Fig. 11 but in which the intersecting grooves in the front side of the plate leave raised portions of hexagonal shape surrounding the bores 2. To this end, again three straight grooves 13, 14 and 15 are provided which extent parallel to the two rows of bores 2. Also provided are a plurality of parallel grooves 20 which intersect the grooves 13, 14 and 15 and extend obliquely of the rows of bores 2 in one direction, and a further plurality of parallel grooves 21 which intersect the grooves 13, 14 and 15 and the grooves 20 and which extend obliquely of the rows of bores in the opposite direction, each of the grooves 20 and 21 passing between two adjacent bores in one row and two adjacent bores in the other row. The grooves can again be readily formed by means of side-milling cutters. After completion of the method in the described manner, a jet nozzle plate is obtained whose jet nozzles are formed by projecting tubes each surrounded by a trough which has a hexagonal periphery defined by lands on the front surface of the plate, so that the individual jet nozzles are again uniformly centrically situated in a free manner.

Obviously, further modifications of the described embodiments are feasible, for example, in the choice of the materials used for the manufacture of the base plate and for the etch-resistant layer to be provided thereon. For example, the base plate may alternatively be made of bronze or a chemically etchable synthetic material, or the etch-resistant layer may be chromium.

CLAIMS

1. A method of manufacturing a jet nozzle plate for an ink-jet printing head, which plate comprises a jet nozzle having a given internal diameter, wherein a base plate from which the jet nozzle plate is to be formed and which is made of a chemically etchable material is first provided with a bore which extends through the base plate and of which at least a portion that opens out of one side of the plate is cylindrical and has a diameter larger than the desired internal diameter of the ultimate jet nozzle, material is then removed from said one side of the base plate by milling so as to leave on said side of the base plate a portion which adjacently surrounds the bore and is raised with respect to the adjoining portion of said side of the base plate, the whole of the base plate including the wall of the bore is subsequently covered with a layer of etch-resistant material which is chemically deposited on the plate to a thickness equal to half the difference between the diameter of said cylindrical portion of the bore and the desired internal diameter of the ultimate jet nozzle, after which the etch-resistant layer is removed from at least the top of the raised portion on said one side of the base plate by grinding in a plane perpendicular to the axis of the bore to a depth which at least equals the thickness of said layer but which is smaller than the sum of the thickness of the layer and the depth to which material was removed from said one side of the base plate by milling, and finally material of the base plate surrounding the bore and exposed by the grinding is removed by etching to leave the etch-resistant material which was deposited on the wall of said cylindrical portion of the bore projecting as a cylindrical tube from said one side of the base plate to form the jet nozzle, the tube being surrounded by a trough formed in said one side of the base plate by the etching.

2. A method as claimed in Claim 1, wherein the grinding is continued until the etch-resistant layer on that part of said one side of the base plate from which material was removed by milling has be n partially ground down.

3. A method as claimed in Claim 1 or 2, wherein the removal of material from said one side of the base plate by milling forms an annular recess in said side of the plate, which recess surrounds and is spaced from the bore in the base plate.

4. A method as claimed in Claim 1 or 2, wherein the removal of material from said one side of the base plate by milling is effected by milling straight grooves in said side of the plate, the grooves intersecting one another so as to form around the bore in the base plate and spaced therefrom a recess in the form of a channel of polygonal shape in said side of the base plate.

5. A method as claimed in Claim 2, or Claim 3 or 4, when read as appendant to Claim 2, wherein the removal of material from said one side of the base plate by milling is carried out to a depth greater than the thickness of the etch-resistant layer subsequently deposited on the base plate.

6. A method as claimed in Claim 3 or 4, or Claim 5 when read as appendant to Claim 3 or 4, wherein a rebate is milled in said one side of the base plate around the edge thereof prior to the deposition of the layer of etch-resistant material, the rebate having the same depth as the recess surrounding the bore in the base plate.

7. A method as claimed in any of the preceding Claims for manufacturing a jet nozzle plate having a plurality of jet nozzles, wherein the base plate is formed with a corresponding plurality of said bores, and wherein around each bore at a distance therefrom a recess is milled in said one side of the base plate so as to leave on this side of the plate a raised portion adjacently surrounding the respective bore, the recesses being formed so as to merge with one another.

8. A method as claimed in Claim 1 or 2, or Claim 5 when read as appendant to Claim 1 or 2, wherein material is removed by milling from the whole of said one side of the base plate except for the portion surrounding the bore.

9. A method of manufacturing a jet nozzle plate, substantially as herein described with reference to Figs. 1 to 7 or any of Figs. 8 to 12.

12. A jet nozzle plate manufactured by the method claimed in any of Claims 1 to 9.

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